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ABSTRACT

A shortage of certified and qualified science and mathematics teachers is one of the most visible and critical problems faced by our nation's schools. Because of the various approaches taken by different groups and agencies to solve the problem, the Improvement of Science and Mathematics Team (ISME) of the National Institute of Education (NIE) was established to identify and describe the most viable alternative to resolve the problem and to focus effort in that direction. The conference reported in this document (one of ISME's tasks) was designed specifically to identify salient elements of the national science/mathematics teacher shortage, add corollary data to the existing body of knowledge, and to influence and guide future NIE research in the area. During the conference paper presenters and discussants focused on possible myths surrounding the teacher shortage, the realities and research concerning science/mathematics education, and the programmatic solutions operated from within and outside of school settings. Included in this summary report are: five research, review, and analytical papers; three case studies of school responses to the teacher shortage; three case studies of business/community/education relationships; three views of the conference; and directions (recommendations) for action. References and list of conference contributors are also included. (JN)

Teacher Shortage in Science & Mathematics

Myths, Realities & Research

National Institute of Education

TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS: MYTHS, REALITIES, AND RESEARCH

A Summary of a Conference Sponsored by the
National Institute of Education,
in Washington, D.C.,
February 10-11, 1983

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PREFACE

A shortage of certified and qualified science and mathematics teachers is one of the most visible and critical problems faced by our nation's schools. Local, state and federal governments, education and science associations, universities, the military and private industry have all turned their attention toward this problem. Collectively, these bodies form a national movement with the common goal of ensuring the nation's role as a world leader in education, science, engineering and technology. The approaches taken to reach this goal, however, are as varied as the movement's participants. Hence, there is a need to identify and describe the most viable alternative and to focus the effort. The Improvement of Science and Mathematics Education (ISME) Team of the National Institute of Education (NIE) was established to fill this need.

The ISME Team is charged with planning and overseeing research on the science and mathematics teacher shortage. The team's specific aims are: (1) to determine and report on the state of the problem, its related issues and solutions, (2) to conduct a national conference on the science and mathematics teacher shortage and (3) to prepare a research agenda on methods of alleviating the shortage. A unique aspect of the team's work is its emphasis on teachers and the nature of teaching in science and mathematics.

One of the team's primary tasks has been completed. A conference entitled, "Teacher Shortage in Science and Mathematics: Myths, Realities and Research," was held in the nation's capitol in February 1983. The conference was designed specifically to identify the salient elements of the national science and mathematics teacher shortage, add corollary data to the existing body of knowledge and influence and guide future NIE research in the area. The conference participants represented people working on all facets of the teacher shortage.

During this conference, paper presenters and discussants focused on possible myths surrounding the teacher shortage, the realities and research concerning science and mathematics education and the programmatic solutions operated from within and outside of school settings. Five research reviews and analyses and six program papers were presented at the conference. A summary paper was commissioned that compiled and critiqued what had been presented, discussed and learned. This latter document includes quotes of key comments, statements of agreements and disagreements, and a concluding section on possible research and practice. This publication is that summary document.

Professor Thomas L. Good, University of Missouri, is the principal author of the conference summary and critique. Dr. Good is a nationally recognized scholar in research on teaching. He has served as a principal investigator on a number of research grants, has published over 70 journal articles, has authored 10 books and has written 40 technical papers. Dr. Good is no stranger to conferences, having made countless presentations at association meetings and universities both here and abroad. He also serves on both education advisory and editorial boards. He is currently the editor of the Elementary School Journal. Dr. Good was assisted in writing the conference summary and critique by Ms. Gail M. Hinkel, a research assistant at the University of Missouri.

We welcome educators, researchers, legislators, individuals from business and industry and others to examine this document and the conference proceedings from which it stems. The proceedings include the papers commissioned for the conference and the edited transcripts of the discussions that followed each paper presentation. The conference proceedings are available from the NIE. Further information about the Institute's research program in science and mathematics education can be obtained from Dr. John L. Taylor of the Improvement of Science and Mathematics Education Team.

Shirley A. Jackson
Associate Director

7

INTRODUCTORY NOTE

The conference was opened by the Honorable T. H. Bell, United States Secretary of Education and Dr. Manual J. Justiz, Director of the National Institute of Education. Their remarks set the stage for two days of invigorating presentations and discussions devoted to the nation's science and mathematics teacher shortage.

Dr. Justiz welcomed the conference participants by noting that the gathering of individuals from such diverse backgrounds typified both the critical nature of the problem we face and the distinctiveness of the event. He accentuated the intent of the conference by commenting that, "...the National Institute of Education is not here to offer a federal solution to the issues being raised on the mathematics and science teacher shortage. The function of the Institute in regard to this conference is to assemble key people in the nation who are thinking about, writing about, looking at and acting on the problems.... After the conference, my staff and I will examine the conference proceedings to determine its implications for future research which can contribute to the improvement of science and mathematics education."

He challenged the participants to question, debate and interpret what needs to be known about the teacher shortage, its myths and realities. Dr. Justiz concluded the opening address by introducing the Honorable T. H. Bell.

The Secretary began his remarks by instructing the participants that, "As you meet to discuss the shortage of mathematics and science teachers it is important for you to consider not only the problems we face today but those we will be facing over the next three to six years." To emphasize his points, Dr. Bell stated that:

1. All across the nation, school boards are increasing high school graduation requirements in mathematics and science. ...for each additional year of study required in either of these fields there will be a nationwide demand for 34,000 additional high school teachers.

2. Teachers are leaving the teaching profession for better paying jobs in the emerging high tech industries. Therefore, we must not only increase the supply of teachers, we must also make teaching more attractive to ensure fewer teacher "dropouts."

3. To date we have not fully grasped the significance of the micro-computer as a force that will change our entire teaching and learning methods from kindergarten to graduate school.

In stating these conditions, the Secretary stressed that, "...we have a responsibility as educators to help America remain the technological leader of the world. As President Reagan observed in his State of the Union Address, 'We must keep that edge, and to do so we need to begin renewing the basics, starting with our educational system.'"

To underscore his concern, Secretary Bell asserted that, "I want every United States citizen to be aware that many other industrialized countries are providing a more intense, rigorous curriculum for their students. They are getting the results they demand. I fear that students in these countries are working to gain the education that could allow the U.S. to sink to the status of a second rate power. We must respond to this massive challenge posed by the other industrialized nations of the world."

The Secretary maintained that, "What we all know is that in order to have quality education, we must have quality teaching." Therefore, "We desperately need to establish the teaching profession as a prestigious, esteemed, and honorable calling. ...I believe (one way to do this) is to establish in American Society a new position of Master Teacher. This new position should be a much esteemed and sought after distinction among teachers. It should ...command a salary commensurate with other salaries that recognize accomplishment and great worth in American Society." Finally, Secretary Bell remarked, "We cannot continue with the status quo and build a truly great teaching profession. The time is long past due for a change."

Following the Secretary's and Director's addresses, Dr. Lee Shulman, Professor of Education and Psychology at Stanford University, was introduced as the conference moderator. He provided the orientation for the remainder of the conference, informing the participants of the operating structure for presentations and discussions, and the outcomes sought. His orientation is captured in the following excerpts from his remarks.

"In an essay by Jerome Bruner, 'The Act of Discovery,' Bruner told of the observation made by a British philosopher that there were basically three kinds of things in this world: First, there are troubles that breed feelings of disequilibrium, of unease, of discomfort, leaving us with a sense that there is something wrong that ought to be responded to, but little else. Second, there are puzzles that have a very clear structure, a very precise formulation and a very elegant design. Finally, there are problems. Problems are what we have when we find an appropriate puzzle to lay on one of our troubles."

Dr. Shulman stressed that the charge of the conference participants was more than the acknowledgment of troubles in science and mathematics education. Rather, the purpose of their attendance was to identify appropriate ways of transforming our teacher shortage troubles into problems through policies grounded in inquiry and research. Professor Shulman concluded by reminding the participants that the focus of the meeting is on the profession of teaching, the conditions of that profession, and the education of science and mathematics teachers.

John L. Taylor
Edward J. Fuentes
Improvement of Science and
Mathematics Education Team

CONTENTS

Page

11

INTRODUCTION

General concern over the quality of American public schools is currently evident. Over 20 major commissions and studies of American education are now in progress (see March 16, 1983 issue of Education Week for a review of these projects). This report is a summary of the papers and discussion that took place during the National Institute of Education Conference on Teacher Shortage in Science and Mathematics: Myths, Realities, and Research.

Because of restrictions on the size of this report, only a small but representative sample of the discussion and critique of papers can be included. The paper contains two major sections. The first is a summary of each paper and the discussion that followed. In the second section we discuss several of the important themes and suggestions for future research that emerged from conference deliberations.

The conference, which was ostensibly convened because of the teacher shortage, spent much of its discussion time articulating a need for curriculum reform (particularly of the quality of coursework) to make science and mathematics instruction more meaningful for the average student. Considering that many students develop a dislike for science in elementary school, merely increasing the number of courses students must take in these areas will not solve our problems. The conference therefore advocates the national study of the current curriculum in mathematics and science, and we concur. The conference did not advocate a national curriculum.

We believe that research on classroom learning and instruction will also be necessary to improve mathematics and science education. This would allow, among other things, identification of successful approaches to instruction in selected mathematics and science concepts which have been identified as important.

Another issue which conference participants agreed is of major importance is the number, and more importantly, the quality of mathematics and science teachers. Participants agreed that competent teachers will be needed to implement an updated, technologically relevant curriculum. In order to attract more talented individuals to teaching and to retain the most competent teachers, many participants advocated a restructuring of the teaching profession and the duties of teachers (teachers would participate in curriculum development, training of other teachers, etc), better working conditions, generally higher salaries, as well as a more diversified career ladder. Along these lines, teacher training programs should be examined in order to identify the characteristics of successful programs. Several participants believe that partnerships among colleges, businesses and schools will be necessary to increase the quality of mathematics and science education for both teachers and students.

Although some immediate expenditures are necessary (e.g., increased salaries), we believe that careful research and development at the national level should occur before most funds are spent. Such research will enable state and local districts to examine more alternatives and to have better criteria for making decisions about improving curriculum and instruction.

RESEARCH, REVIEW AND ANALYTICAL PAPERS

SUPPLY AND DEMAND FOR SCIENCE AND MATHEMATICS TEACHERS
Betty Vetter

Evidence of Shortage of Science and Mathematics Teachers

A survey of 50 state secondary science supervisors in 1980-81 showed that 43 of 50 reported shortages of physics teachers and 35 of mathematics and chemistry teachers. This shortage is critical and worsening. A December 1981 National Science Teachers Association (NSTA) survey found that from 1971-1980 there was a 68 percent reduction in newly employed science teachers and an 80 percent reduction in newly employed mathematics teachers. Another NSTA survey (December 1981) of 2,000 secondary principals showed that 52 percent of newly employed teachers were unqualified to teach science and mathematics. There are especially serious problems in states where high technology industries hire the best-trained science and mathematics personnel (Pacific and West South Central States).

Number of New Graduates

Nationwide, the number of new teachers graduated in the last 10 years has dropped from 36 to 21 percent of all college graduates. The number of science (a drop of 891 to 597) and mathematics (2,217 to 798) education graduates has also declined. Only 5 percent of all college-bound seniors plan to major in education, and only 1.3 percent of all education majors graduating in 1981 majored in science or mathematics education.

Shortages in the States

No national data are available, but several states have made surveys. For example, in North Carolina the percentage of new mathematics teachers as a fraction of all new secondary teachers has declined steadily since 1967. Furthermore, in no year were more than 50 percent of the prior year's graduates actually teaching. Only 55 percent of North Carolina's mathematics teachers are certified in mathematics.

Teacher Exodus to Industry

There is a serious exodus of experienced teachers. Five times more people left mathematics and science teaching for non-teaching jobs last year than for retirement. There is evidence that those leaving are the best qualified.

Quality of New Science and Mathematics Teachers

There has been a drop in the quality of new graduates preparing for secondary teaching. The Scholastic Aptitude Test (SAT) scores of students planning education majors are considerably below-average. Graduate Records Examination (GRE) and National Teacher Examination scores also show that students currently enrolled in teacher education programs are the least competent compared with those preparing for other professional careers.

Students planning to major in education also had lower Grade Point Averages (GPA'S), had taken fewer high school mathematics and science courses and fewer courses in academic subjects than other college aspirants. These differences are greater for males than females, but they exist in both cases. Among women, differences in academic qualifications between those planning to major in education and those entering other fields appear to be widening (white women make up 67 percent of those planning to major in education).

Concerning eduation majors, Virginia reports that these students scored an average of 100 points lower on the SAT than majors in other areas.

Test scores. Since 1962 mathematics scores on the SAT have fallen steadily. There has been a sharp drop in students' ability to apply classroom theory to numerical problems of everyday life from 1973-78. There has also been a steady decline in science achievement scores from 1969-1977. Scores have been getting lower on four other tests also. The SAT decline, however, has leveled from 1980-82.

Declining scores may be part cause and part effect of a shortage of qualified mathematics and science teachers. Some educators attribute the drop to "new math," while other studies show that students using these curricula do better.

High school graduation and college entrance requirements. Since 1970, requirements for high school graduation and college entrance have been lowered. Only one-third of U.S. school districts required more than one year of mathematics and science for graduation in 1982, and one-half of all high school graduates take no mathematics or science after the tenth grade. Colleges have thus been forced to extensively increase the number of remedial courses they offer. There has also been a decline in the number of science courses taken by college students not majoring in science or related areas. The proportion of high school students fully prepared to major in a quantitative field is less than one-third of all graduates, and less than one-fourth of those who enter college.

Despite extensive efforts to recruit women to science and engineering fields, they consistently take fewer high school mathematics and science courses than men. Comparing the average number of semesters of science and mathematics taken in grades 10-12 by high school seniors in 1972 and 1980, there is some increase in mathematics (3.6-4.1). However, a small increase in science courses taken by women was accompanied by a slight decrease among men.

Cause or effect? Some possible causes often given for the declining number and quality of secondary science and mathematics teachers may in some cases be effects instead. For example, have SAT scores declined because of poor or uninspired teaching, or has the continuing decline in test scores resulted in lower quality among those who seek to enter teaching careers?

Some of the reasons for the teacher shortage are obvious (e.g., low pay). Other reasons are: National Science Foundation (NSF) funding for summer teacher workshops and other inservice training, and for college science and engineering education has declined steeply over the past 22 years; and support for pre-college science education has dropped even more sharply, to a presently minimal level. While there is not necessarily a cause and effect relation, considering other evidence, such a relationship appears likely.

Curriculum development. There have been almost no curriculum development efforts since 1962. There is evidence that students using the "new" curricula produced in 1962 with NSF support score better on attitude, achievement, and process skills (overall 14 percent higher). Low social economic status (SES) pupils scored 24 percent higher. However, these evaluations were done in the 60's and 70's and few teachers now teaching are qualified to teach the new curriculum. Further, the curriculum needs modifications to account for developments in the past 20 years (i.e., computers).

International Comparisons

Japan, Germany, and the U.S.S.R. provide rigorous training in science and mathematics for all citizens. The U.S.S.R. offers properly sequenced material in these areas, whereas in the U.S., pupils are introduced too soon to abstractions without prior steps, and many students fail or drop out.

Public Support for Science and Mathematics Education

The public does not understand the importance of a good background in mathematics and science, but there is some evidence that their understanding is increasing (i.e., increased congressional support). Some states are supporting improved mathematics/science education by raising standards of eligibility for teacher education (but without incentives to attract better students) and by raising requirements for high school courses, especially in English and mathematics. Public opinion polls show that people are willing to support mathematics/science education with taxes. A Gallup Poll shows that 97 percent of the public see mathematics as "essential" and 83 percent view science similarly.

Consequences of the Teacher Shortage

Many schools have dropped courses and used uncertified teachers. We need better high school preparation in science and mathematics to rectify the teacher shortage. We also need an informed electorate. A national study done in 1980 shows that only 18 percent of U.S. adults are interested and informed about scientific matters. Although some improvements are being made, Vetter thinks teacher salaries must be raised and pre-college mathematics and science education improved in order to alleviate the teacher shortage.

Conference Discussion

In the discussion that followed, Steve Davis questioned whether industry attracts mathematics and science teachers or whether other careers attract all teachers. "In other words, the statistic I would be interested in is whether the percentage of science and mathematics teachers leaving for other careers is significantly higher than just teachers in general leaving for other careers." Although no one had specific data, there were anecdotal data to support the notion that teachers in all areas are leaving teaching.

Al Buccino acknowledged that the data presented by Vetter could be variously interpreted and suggested the need for long-term study of the teacher shortage. In his opinion, the problem is 10 years old and he therefore suggested identifying the type of information and monitoring that would be needed to study this issue.

NATIONAL NEEDS FOR SCIENCE AND TECHNOLOGY LITERACY--
THE ARMY AS A CASE STUDY

Wilson K. Talley

The paper by Talley is based partly on a November 1982 report by the Army Science Board. This group was commissioned to evaluate and make recommendations (for the Army as well as other groups) concerning several "trends" in United States science and engineering (S&E): (1) a national shortage of scientists and engineers, (2) a loss in the "technology" race with other countries, (3) curriculum problems in primary/secondary mathematics and science and (4) instruction/facility limitations in universities. Briefly, the Board concluded that the Army has no shortage of S&E's, and that problems are more likely to be related to quality of personnel rather than quantity. Nevertheless, the report states that the Army is concerned about the generally low national level of technological literacy.

Supply and Demand Estimates

Supply--and to a greater extent, demand--estimates of future scientific talent are very unreliable (e.g., sampling bias), although statistics about a particular area are more accurate. Furthermore, students must usually make the decision to pursue a career in S&E by the 11th grade. However, students' most common source of information about job opportunities is television and newspapers, where the information usually concerns unemployment, with only an occasional report of a shortage. Because of the 6 to 10 years required to train S&E's, the U.S. tends to have cycles in its supply of S&E's.

In the end, the most important factor in evaluating the validity of supply/demand predictions may be who is making the forecasts. For example, those associated with industry usually predict shortages, hoping to attract more students and eventually to more easily and cheaply obtain S&E's. Conversely, professional societies most often predict a bleak future for S&E jobs in an attempt to protect their members' careers. Finally, colleges and universities take a middle stance; they need S&E students, but their graduates must also have jobs.

As stated earlier, neither statistics nor interviews with Army Research and Development (R&D) managers indicate that the Army is unable to attract and retain an adequate number of S&E's. (The Army employs only 1.2 percent of all S&E's.) However, in the event of a serious shortage, and in attempts to hire quality personnel, the Army is at a disadvantage compared to other institutions (e.g., time-consuming hiring procedures, lower pay).

Reducing Demand

Even though the Army seems to have a sufficient number of S&E's, there is a definite lack of objective indicators concerning their quality. It makes little sense for the Army to spend millions on increasingly higher technologies (e.g., computers), if no people to maintain, operate and repair the systems are available.

There are several ways to correct imbalances between supply and demand. First, the Army may need to change the way it uses defense contractors. Competition among several contractors may result in largely wasted effort by many of the best S&E's of the losers. Furthermore, many Army design criteria emphasize low initial cost over procedures for upgrading a system once it is operating.

Increasing Supply

Training scientists and engineers. Data compiled by the American Society of Engineering Education indicate that the overall student/faculty ratio in U.S. engineering schools has increased almost 50 percent since 1974, and the number of new engineering Ph.D.'s has been declining since 1972. If these trends continue, the quality of undergraduate engineering education is likely to deteriorate.

As possible solutions to these problems, in June 1982 the deans of 287 accredited engineering schools recommended a short-term reduction in undergraduate enrollment and incentives to increase the number of graduate engineering students. However, other, less drastic solutions are discussed below.

Increasing the high school graduate pool. There has recently been much concern over the lack of scientific and technological literacy of most high school graduates. Many factors contribute to this situation. First, few secondary pupils (about one-sixth) take any mathematics or science courses beyond the 10th grade. Only one-third of 17,000 U.S. school districts require more than one year of mathematics or science to graduate. However, the pool of high school graduates that could major in S&E is still larger than the number who do major in these fields. In fact, fluctuations in the number of S&E majors in college are more dependent on high school students' perceptions of career opportunities than on the quality of secondary mathematics and science education.

Increasing general technological literacy. A more serious difficulty is the ability of the increasingly technological U.S. society to function well if citizens do not understand technology better (i.e., uninformed electorate). For the Army, this means that newly recruited or enlisted personnel must receive extra technological training. Some high school graduates with little background or aptitude for mathematics and science go on to college and some choose to be primary and secondary teachers. Because few of these people take advanced mathematics or science in college, few are well qualified to teach these subjects. The National Science Teachers Association found in a recent survey of the Pacific States that 84 percent of newly employed science and mathematics teachers are unqualified to teach in these areas. In addition, a study by Hurd (1982) indicates that 50 percent of U.S. teachers hired to teach mathematics or science in 1981-82 were unqualified or teaching with emergency certificates. And, of course, because even qualified teachers in these areas are rarely compensated adequately, many switch to jobs in business and industry. Finally, students who are taught mathematics and science by teachers who are ill-prepared to teach these subjects are not likely to be very interested in taking more courses in these areas.

Solutions and the Army's Contributions

First, the demand for scientists and engineers should be reduced. In addition to the methods mentioned earlier (reduce competition among contractors, design systems which can easily be improved), computers should be used for various types of S&E work.

Second, new S&E's must be provided and the skills and talents of existing S&E's need to be upgraded. For example, defense contractors could be allowed 100 percent recovery of university-related expenditures for fellowships, equipment, etc. The Defense Department itself can also directly aid universities by expanding scholarships in relevant areas, employing faculty as consultants and establishing and supporting "Centers of Excellence" at universities (particularly in neglected research areas). A major goal related to these activities should be stability in funding patterns which will create pools of talent and products in specific, vital areas.

A third and more drastic solution is that the Department of Defense participate in the college education of S&E's and in conducting research.

A final recommendation is that the Defense Department (which has laboratories throughout the country) also contribute to science and mathematics eduation in primary and secondary schools by providing release time to government S&E's to teach in public schools (certification requirements would need to be waived); providing equipment and laboratory facilities; starting enrichment programs; and supporting the work of commissions who are investigating mathematics, science and technology education.

Conference Discussion

In the discussion that followed, Bill Aldridge indicated that he agreed with Talley's assertion that we should be concerned about improving the technological literacy of the population in general rather than better training of scientists and engineers. He stated, "we all know that the curricula of the '60's in the secondary schools were designed principally to prepare scientists and engineers. We also have firm evidence that those curricula are inappropriate to the present student body, that is, for the majority of them. Now our concern is, in all the federal programs, in all the bills that have been introduced in Congress, none has proposed large national efforts at redevelopment of the curricula. Instead, they want to provide all 17,000 school districts with an opportunity to reinvent the wheel in all 17,000 places."

Most conference participants believe that major curriculum reform is needed. Vetter and others suggested that we are in desperate need of new curricula and Lee Shulman argued that forcing students to take the same chemistry or algebra II they have been avoiding the last 20 years is no answer.

There was general agreement that curriculum reform is too complex and too expensive a task for an individual school district or state, and thus an agency like the National Institute of Education must help coordinate the study of reform. For example, Doug Lapp, science coordinator from the Fairfax County Schools in Virginia, noted that although his school district is the tenth largest in the nation and perhaps has the highest median income, the district could not attempt curriculum reform alone. As Lapp stated, "...and I'd like to say we just don't find it possible, and I don't think we ever will, to assemble the expertise to develop curricula of the quality that is required in science and technology and keep those current...local districts can assume control and maintain control over the curriculum by using an eclectic approach, by combining elements developed from various projects into things that fit local situations, local capabilities, and facilities. But in no way can they develop curricula without academic support from universities..." He suggested that the national curriculum projects in the '50's and '60's were excellent models that need to be duplicated by development efforts in the '80's.

RESEARCH IN SCIENCE EDUCATION: REVIEW AND RECOMMENDATIONS

Wayne Welch

Introduction & Problems

In the past decade science education has suffered from declining test scores, shortages of qualified teachers, loss of federal support and less curriculum time. Some persons claim that a national crisis exists. However, in the past few months a renewed interest in this area has been reflected in the doubling of NSF's budget for science education, increased attendance at national meetings, the establishment of a commission on pre-college education in mathematics, science and technology and the increased work of professional societies. Furthermore, results of the 1981-82 national assessment (Welch & Anderson, 1982) indicate that declines in science achievement at ages 9, 13 and 17 have stabilized.

Synthesis of Recent Research

This research review (a needs assessment of research) covers the total domain of science education (contexts, transactions, and outcomes--see Table 1).

Welch's definition of a needed area of research has three aspects: (1) gaps in knowledge in an important area, (2) high national priority and (3) a promising area that has little prior research.

Major data sources for Welch's review were: yearly reviews of research supported by ERIC-SMEAC, several meta-analyses, the NSF-supported status studies, national assessment results and the work of Project Synthesis.

Welch concludes from his review that the seven most promising (moderate amount of research thus far; evidence of effect) areas for needed research are: school climate; home environment; student behaviors; resource exposure; career choices; student attitudes and classroom climate. Welch notes that the absence of teachers and teaching behaviors from this list surprised even him. However, except for the influence of teacher training programs on teachers,

TABLE 1

Domain of Science Education
Examples of Categories

1. Context (entry conditions)

   a. Student Characteristics (i.e., interests, previous experiences, abilities, attitudes)
   b. Teacher Characteristics (i.e., philosophy, preparation, perceptions, personal traits)
   c. Science (i.e., content, processes)
   d. School Climate (i.e., bureaucracy, policies, physical appearance, community influences)
   e. Societal Imperatives (i.e., environmental quality, societal views of science and/or technology, health and well being)
   f. Home Environments (i.e., vocation, family structure and function, physical features, philosophy)
   g. Curriculum Materials (i.e., texts, laboratory guides, films)
   h. Science Facilities (i.e., classroom/laboratory, materials, budget)
   i. Goals (i.e., philosophy, students, school board and other outside groups, departmental)
   j. Science Education Network (i.e., communication groups, professional societies, research reports, cooperative efforts)

2. Transactions (interactions)

   a. Teacher Behaviors (i.e., procedures followed to promote instruction)
   b. Student Behaviors (i.e., activities of students in the classroom)
   c. Instructional Resource Exposure (i.e., enrolling in science, TV, engaged time)
   d. External Influences (i.e., strikes, budget cuts, space launchings)

3. Outcomes (results of instruction)

   a. Student Achievement (i.e., test scores, other measures)
   b. Student Attitudes (i.e., student feelings about science and science learning)
   c. Student Skills (i.e., observation, measurement)
   d. Teacher Change (i.e., satisfaction, burn-out, knowledge)
   e. Scientific Literacy (i.e., more knowledgeable concerning meaning, limitations and value of science)
   f. Career Choices (i.e., science or science teaching)
   g. Institutional Effects (i.e., loss of status, narrow-focus, structure changes)

extensive study of teachers "has not yielded promising results." The mean correlation of teacher characteristics with teacher behavior was only .05, and teacher behaviors had a mean effect size of .22 on student outcomes. Students' activities and characteristics and the context in which learning occurs seem to have more potential for future research in science education.

Other Needs Assessments

Table 2 shows the research priorities of five other recent needs assessments in which information was gained through survey techniques (e.g., teachers; university science educators). Welch examined these five assessments in relation to his definition of the domain of science education. Several conclusions are apparent from Table 2. First, Welch's research needs analysis, which is based on the extent and effect of prior research, results in different priorities than those yielded by the survey techniques. Second, survey needs assessment emphasizes teachers, curriculum and student cognitive development. Welch's review did not emphasize these areas because a great deal of work has already been done, and the studies thus far are not very promising. Third, environmental influences (e.g., home, school, classroom) are almost totally ignored in the surveys as potential areas for study. However, Welch's synthesis indicates that these are promising topics. Fourth, career choices in science and science teaching were not ranked high in most of the surveys, perhaps because the surveys were conducted in 1976-79, and most of ~~the~~ teacher shortage concerns have only been voiced in the past few years. Finally, four aspects of the science education domain were not highly ranked in any of the studies: student skill outcomes; changes in teachers resulting from the teaching process; institutional change and external intrusions.

Because there has been little research in the kinds of behaviors students exhibit during learning, it is not surprising that the five surveys did not include research in this area. However, Welch argues that "if students are considered the primary actors in the learning process instead of teachers, then the study of appropriate behaviors (e.g., engaged time) seems highly desirable."

Research Questions

Welch believes that answers to the following questions will help most to improve the teaching and learning of science:

1. How and to what degree do the environmental conditions of the home, school and classroom influence science learning?

2. How can student attitudes be measured more effectively and what factors determine these attitudes?

3. What facilitates or impedes students' exposure to the necessary instructional resources (science learning opportunities)?

TABLE 2

Summary of Research Priorities

Element	Welch	NIE-NARST	Butts et al.	Yeany	Yager et al.	Abraham
Context						
Student Characteristics		x	x			x
Teacher Characteristics		x	x	x		x
Science			x			
School Climate	x					
Social Imperatives		x				
Home Environment	x					
Curriculum Materials			x	x	x	x
Facilities/Equipment				x		x
Goals			x			x
Science Education Networks					x	
Transactions						
Student Behaviors	x					
Teacher Behaviors		x	x	x	x	x
Instructional Resource Exposure	x	x		x		x
Classroom Climate	x	x				
External Intrusions						
Outcomes						
Student Achievement			x	x	x	x
Student Attitudes	x	x	x	x		x
Student Skills						
Teacher Change						
Scientific Literacy		x			x	
Career Choices	x			x		
Institutional Change						

Xs are unranked

4. What specific student classroom behaviors are necessary for effective science learning?

5. What determines the science career choices of students and teachers and how can these decisions be influenced?

The research outlined above is needed to determine the causes of shortages of science teachers and career scientists, declining enrollments in science classes, and lower science literacy among the population and to identify means of reversing these trends.

Conference Discussion

There were two discussions of Welch's paper. The first discussant, Rustum Roy, strongly reinforced themes that had been expressed earlier in the day. Specifically, he argued that the goal of science/mathematics education should be to make the average citizen technologically literate. The problem from his perspective is not the training of the top one percent of students, but the curriculum that average students receive. He also acknowledged the need for curriculum reform and emphasized that the curriculum is too abstract and does not contain enough application.

Although the other discussant, Robert Yager, generally agreed with Welch's paper, he expressed some disappointment in Welch's emphasis on content (the facts of science) rather than the process of science. He suggested that a philosophical perspective should be added to Welch's conceptualization of the field (see Table 1): "It seems to me that this lack of the philosophical perspective, a lack of any view as to what science teaching is about, and what science education is about and what the fundamental mission of our discipline is, is a problem."

Yager stressed the mismatch between the science that is being taught and that which is needed (as did Roy). He suggested that the curriculum used in most classrooms is inappropriate for 95 percent of our students. Yager also stated the need for more attention to instructional theory and the study of teacher behavior. It is worth noting that although Welch did not advocate research on teacher behavior, all five of the other recent attempts to identify research priorities that he cites recommmend additional work in this area (see Table 2).

According to Yager, "...we have paid no attention to instructional theory. And again it is fair to say that there is a mismatch as far as what is being done, the strategies that are being followed and what we know should take place.... As we have gone around visiting six centers of excellence, we have been amazed at the number of these programs where there has been a concern for curriculum, but there is practically no knowledge of and no interest in instruction. And we think this is a serious problem."

Despite the problems of curriculum and instruction, Yager contends that there are some exemplary programs and teachers and he suggests that one reason these are excellent is because they understand what they are attempting to accomplish. He suggests that data clearly indicate that the longer students study science the less comfortable they report being with this subject; hence, more teachers and the same curriculum will not alleviate problems in this area.

One of the authors was asked by Lee Shulman to respond to Welch's paper, when Shulman expressed some concerns with Welch's position: "I, too, have some fairly serious quibbles with Welch about his meta-analysis, especially with respect to teaching behavior, but I trust that Tom Good will handle that one..." We will take this opportunity to respond.

In general, Welch's paper is a useful characterization of science education in the past, present and future. However, we believe that the study of one aspect of the learning situation independent of other variables is unproductive. Thus, the call for increased research on students, independent of instructional behavior and the curriculum tasks that students are assigned, will not be as useful as more integrative research.

Welch is correct in arguing that teacher behavior research has been relatively unproductive historically. An unfortunate aspect of many meta-analysis reviews is that they equate all studies, irrespective of the quality of any individual study. Meta-analysis process-product data are especially suspect because so few studies are available that were able to measure both teacher behavior and student learning with depth and validity. Until very recently, most teacher behavior measures involved frequency counts of primarily affective behaviors so it is not surprising that they did not relate very strongly to student learning gains. Important advances have been made in recent classroom studies (e.g., more and better measurement of classroom process, more adequate sampling of teachers, more emphasis on the context in which teaching occurs, etc.) As Gage and Giaconia argue (1981), recent and more sophisticated studies of instructional behavior provide convincing evidence that variations in teacher behavior (in well controlled field experiments) are related to student achievement and illustrate that knowledge of instructional process can have important practical value. Awareness of such recent improvements in research on teaching is no doubt partly the reason that other recent attempts to establish research priorities have consistently argued for more research on teaching. Hence, we too advocate that caution be used when results from general meta-analyses are interpreted (as do Lee Shulman and others at the conference...for a useful discussion of problems of meta-analysis, see Biddle and Anderson, 1983), and agree that more research on instruction is needed (a proposal also made by Robert Yager and others at the conference).

We also believe that more study of students is needed (for an especially good example of the usefulness of classroom research on students, see a special issue of the <u>Elementary School Journal</u>, May 1982, edited by Rhona Weinstein). However, research on student factors will likely be more effective if it is integrated with teaching and curriculum work.

Similar concerns were expressed by conference participants. For example, Naama Sabar suggested that student initiative and task involvement could not be explained independent of teacher guidance and action (e.g., the type of homework assignment). Judith Lanier cautioned that we should not substitute research on students for research on teachers and added that we need studies of cognitive processing of teachers and learners as well as studies of classroom behavior.

TAKING MATHEMATICS TEACHING SERIOUSLY: REFLECTIONS ON A TEACHER SHORTAGE

Jeremy Kilpatrick and James W. Wilson

The thesis of Kilpatrick and Wilson's paper is that the current shortage of mathematics teachers reflects the negative attitudes of society and the educational community towards mathematics, its teaching, and those who teach it. In fact, most people do not take the teaching of mathematics seriously.

The shortage is more apparent in secondary schools; however, there is also an inadequate number of elementary teachers who are knowledgeable about mathematics and feel comfortable teaching it. The problem at the two levels is different, and long-term solutions may be harder to implement in elementary schools. Most of this paper, however, concerns problems at the secondary level.

Reducing the Shortage of Mathematics Teachers

In examining various ideas for reducing the shortage of qualified teachers, Kilpatrick and Wilson note that there is frequently a clash between short-term and long-term goals. That is, many proposals which might alleviate the current shortage seem unlikely in the long run to make mathematics teaching an attractive profession which can attract and retain superior teachers.

1. Raise salaries for mathematics teachers. Higher salaries seem to be the most popular solution to the shortage of qualified mathematics teachers. Aside from finding money to raise salaries, there are problems with providing differential pay for a particular group of teachers without increasing the pay for all teachers (e.g., teachers' groups lobbying against each other).

   One example of a workable program to encourage persons to become mathematics teachers is one proposed in the United Kingdom, which associates increased pay for mathematics teachers with tenure, a specialization in mathematics, proportion of school day spent teaching mathematics and teaching competence. Extra pay is not given during the first two years of teaching. Kilpatrick and Wilson note that such proposals allow a great deal of local control, which might or might not be more effective than state or national control in recruiting and retaining competent mathematics teachers.

2. Provide incentives to preservice teachers. Many persons see grants or loans (which are repaid by teaching) to college students agreeing to teach mathematics for a certain number of years after graduation as a quick solution. If the career of mathematics teaching is not made more attractive, however, such incentives are likely to attract people who are only teaching temporarily in order to repay loans.

3. Change requirements to become a mathematics teacher. Some persons contend that the mathematics teacher shortage is so severe that certification requirements should be altered. By doing so, people trained to teach in other fields, but who do not qualify for certification in mathematics, could teach. However, this procedure could eventually result in the employment of underprepared teachers and would limit the hiring of better qualified teachers.

   Students preparing for careers in business and industry might be enticed into teaching for a few years through incentives provided by business. All the proposals discussed so far assume that more money is the key to solving the shortage. However, Kilpatrick and Wilson believe that in the long run teachers' attitudes (commitment to teaching, morale) are more important than money. According to these authors, the solution to the shortage is not simply more money (although this will be necessary), but recruiting more students, retaining competent teachers and helping underqualified teachers to improve or to leave the profession.

How the U.S. Approaches Educational Problems

It is noteworthy that none of the proposals discussed thus far has come from teachers themselves. Kilpatrick and Wilson point out that educational problems in the U.S. have traditionally been solved from the top down, without much attempt to determine what problems exist in the classrooms. In fact, many educators, administrators, and policy makers who deal most directly with educational problems have not been in many classrooms recently. Although Kilpatrick and Wilson emphasize that teachers must be heard, they discuss several other factors (below) which are involved in the solution of problems associated with mathematics education.

The U.S. Mathematics Curriculum

Past curricula. In this century the mathematics curriculum has been affected by numerous groups (e.g., school boards, mathematicians, test developers), but input from mathematics teachers has usually been ignored. From 1900-1923 educational generalists questioned the importance of mathematics instruction in schools. In the 1930's and 1940's mathematics began to generally be viewed as socially useless and its importance in the curriculum declined.

In the mid-1950's a back-to-basics movement began, and the "new math" was introduced, but without any attempt to enlist the support of teachers. Because of this, the new mathematics was never fully implemented in classrooms, although its effect was much more pronounced in secondary than in elementary schools. Secondary textbooks and curricula changed considerably, though most of the alterations have now disappeared.

Because of the perception of the new mathematics as a failure, there was another back-to-basics, movement in the 1970's (although many schools had never given up this approach). The result was a drill-and-practice approach to instruction, and in 1980 National Assessment results showed that most students were unable to solve simple problems (Carpenter et al., 1981).

A recent report, the Agenda for Action of the National Council of Teachers of Mathematics, presents recommendations for school mathematics in the 1980's which do utilize input by mathematics teachers. This report recommends emphasizing problem solving and applications; re-examining basic skills; using calculators, computers, etc. in mathematics instruction and more mathematics for all students. However, the curriculum has not yet been much affected by this report, textbooks are similar to those published in the 1970's and instruction still consists primarily of drill-and-practice.

Kilpatrick and Wilson agree with the changes advocated in the report, but believe that these changes cannot occur without competent, well-trained mathematics teachers implementing the changes in their classrooms. In order to accomplish this, teachers will need more and better training, and some will need retraining.

How the curriculum has been viewed. Currently many mathematics classes are boring and repetitive. They are seen by most students, and perhaps by many teachers, as a necessary evil. To mathematics educators and many mathematicians, mathematics has numerous aspects (e.g., problem solving, number theory, statistics) and is challenging and exciting. The general public and perhaps many teachers, though, view mathematics as paper-and-pencil computations. When mathematics educators advocate organizing the curriculum around problem solving, the public agrees and interprets this as word problems which allow pupils to practice manipulative skills. Mathematics educators, however, have in mind a much wider definition of problem solving.

Teacher's role in curriculum change. The U.S. attitude towards curriculum reform is that "more is better," that new curricula and textbooks are successful in relation to the number of states which adopt them. The traditional myth in this country has been that the local community determines the curriculum. However, this process is disappearing as our society becomes increasingly mobile and parents who move do not want their children to "miss anything important." National college entrance tests, textbook publishers, and curriculum development projects also contribute to a uniform mathematics curriculum. However, teachers have not been true collaborators in curriculum development. Kilpatrick and Wilson believe that teachers much understand and be intimately involved in change and must be educated to do so.

Mathematics Teaching in the U.S.

What mathematics teaching has been. In the past teaching was one of the most open professions, particularly to talented women and minorities. However, persons from these groups who are well educated in mathematics can now choose from many attractive undergraduate majors and careers, and there has been a resulting decline in the teacher candidate population. According to Kilpatrick and Wilson, mathematics teaching must be presented to talented mathematics majors as a challenging and rewarding career.

What teacher education has been like. Even in 1960 the mathematics education of a typical elementary education major consisted only of two years of high school mathematics, one college course in general mathematics, and one methods course. The median number of semester hours of mathematics required for high school teaching was 15. A 1959 survey of high school teachers indicated that 7 percent had taken no college mathematics and only 61 percent had studied calculus or more advanced courses (Gibb, Karnes, & Wren, 1970).

Kilpatrick and Wilson argue that mathematics teachers need a knowledge of mathematics and pedagogy, and that "one should not be pitted against the other" in an effort to improve the quality of teacher preparation.

They also believe that mathematics educators have been too concerned with preparing teachers to survive the first year of teaching (e.g., classroom management) at the expense of providing them with long-term skills which would be useful in areas such as curriculum development, comparing curricula across grade levels, etc. In essence, teachers "have not been prepared to be mathematics educators."

Summary/Conclusion: What Mathematics Teaching Should Become

How persons view their work is important. A series of studies sponsored by NSF (Fey, 1979a, 1979b) indicates that today many teachers do not have a sense of commitment that may in the past have helped them to overcome the hardships of teaching.

Kilpatrick and Wilson believe that the long-term quality of mathematics teaching will largely depend on the kind of people recruited to the field. They argue that teaching today is simply not as attractive a career as it used to be, and the responsibility for having made it so must be shared. Finally, they suggest that teachers must be involved in research, and that they should be trained to review and critique research results.

Conference Discussion

The paper by Kilpatrick and Wilson was followed by three discussants. Antoine Garibaldi suggested the need to examine the public school mathematics curriculum and in particular to determine how the curriculum can be adjusted to meet the demands of today's technological society. He cautioned against issuing large numbers of emergency certificates and warned that many underprepared teachers may return to the classroom to meet emergency certification requirements in order to improve their financial status rather than to improve their mathematics teaching.

Andrew Porter advocated the study of the relationship between teacher knowledge of mathematics and student classroom performance, citing a paucity of research evidence. Until such research is done, it is obviously difficult to determine how to improve teacher training programs. He also wondered about the efficacy of certification in subareas of mathematics. He reasoned that preparation in a subarea might alleviate the need to train all new teachers in the broad field of mathematics.

Porter also argued for comparative research to determine what steps other countries (e.g., Japan) have taken to prevent teacher shortages in mathematics and science. He believes it is also important to study the mathematics curricula and instruction in countries which have done an excellent job of preparing citizens for life in a technological society.

Porter presented several arguments to challenge Kilpatrick and Wilson's position that mathematics was becoming a less attractive subject to teach. For example, he noted that mathematics is viewed by the public as essential and that the proportion of high school teachers with mathematics as their primary assignment has risen from 11 to 18 percent since 1961. Porter suggested that these (and other) limited data do not support the contention that mathematics teaching is unattractive; rather, he believes the problem may be that teaching in general is not taken seriously enough.

Porter notes that Kilpatrick and Wilson advocate curriculum reform on the NCTM "Agenda for Action in the 1980's," which emphasizes problem solving and applications. He suggests that Kilpatrick and Wilson are somewhat ambivalent concerning solutions to curriculum problems. He noted that the NCTM paper is a national agenda and added, "...Jeremy and Jim state that, one, the school board should have ultimate responsibility for the curriculum; two, the arena for action is in the classroom; and, three, teachers should have greater autonomy and be more involved in curriculum development. These statements suggest a certain ambivalence about the determinants of school curriculum..."

In work at Michigan State University, Porter and colleagues have found in several studies that elementary school teachers are reluctant to take responsibility for making mathematics content decisions, although they are forced to make such decisions because of lack of authoritative advice from school administrators or because of conflicting school policies that have to be resolved at the classroom level. In contrast to Kilpatrick and Wilson, Porter suggests that elementary school teachers do not want total autonomy in deciding what mathematics to teach.

We believe that Kilpatrick and Wilson are correct in arguing that teachers should be involved in curriculum content decisions (especially if they receive additional training for this task); however, the task is too general and too demanding for an individual teacher or school district, and new curriculum alternatives must necessarily be constructed on a national level. Porter's call for more research and curriculum conceptualization is important.

Jack Easley, the third discussant, primarily described recent research he has been involved in, and discussed mathematics teaching in an inner-city Japanese elementary school. The teachers in this school gave children challenging problems, allowed them to teach each other, and generally did very little active teaching. He suggests that one of the key features of mathematics instruction in this school was that the teachers never gave students much mathematical instruction. He notes, "The teachers were excellent masters of ceremonies. They used very little of their knowledge, whatever knowledge they might have of mathematics, in teaching these mathematics classes. They almost seemed, as the teacher I described, to hold it back and keep it away from the children and let the children struggle with it themselves." Easley suggested that American students would benefit from more peer instruction and less teacher direction.

As mentioned above, Andrew Porter advocated more cross-cultural research as one way to inform and to perhaps improve mathematics and science teaching in the United States. Porter's call is an important one and Easley's case study raises some significant and useful questions. However, we wonder what type of teaching occurs in United States classrooms in more advantaged neighborhoods where parents and teachers are quite serious about how much and how quickly students learn mathematics. If "student controlled" learning is dominant in such settings (which we doubt) then Jack Easley's arguments for more peer teaching are much more compelling.

One of the authors of the present paper stated during this discussion session that learning is not always optimal when students teach other students. There are considerable data collected by a variety of researchers (Noreen Webb at UCLA, Penny Peterson at Wisconsin and Robert Slavin at the Center for Social Organization of Schools) which indicate that peer tutoring or instruction does not automatically solve instructional difficulties. Some combinations of students make more progress in learning particular concepts than others and in some instances student-directed learning is very unproductive for some students.

However, we do not advocate that instruction be solely teacher-directed. No type of instruction predicts successful learning independent of quality of teaching. Student-directed learning can be beneficial. However, careful research should guide construction of such learning situations and the identification of which concepts and processes are most amendable to discovery or to expository approaches. Thus, we believe that the recommendation that teachers withhold information from students is unwise. Certainly, the amount and/or timing of information teachers provide can be incorrect, and Easley's suggestion that many teachers do not encourage students to think creatively about mathematics is a useful caution. Further, more research is needed on how to increase students' mathematic reasoning by varying the structure and process in mathematics classes.

Lee Shulman put the discussion into perspective in the following way "...I think in both the outstanding work that people like Tom Good have done, and the work that Jack Easley has done, though they may not agree on the particulars of teaching, neither of these approaches views teaching as lots of telling, and better teaching as more telling." More basic research that describes how students can be helped to understand more fully both the content and processes of mathematics and science is needed. Shulman suggests that additional research may help clarify how we should train/educate teachers, and that until such research is done we will not improve classroom teaching by simply asking teachers to take more mathematics and science classes.

PREPARATION OF TEACHERS: MYTHS AND REALITIES
Anne Flowers

Recent advances in technology mean that knowledge is out of date before it can be incorporated into school curricula. At the same time, there is a shortage of technologically knowledgeable teachers, and of qualified teachers in general. These problems are exacerbated by the lack of incentives to attract students to teaching.

The solution to the shortage of mathematics and science teachers will only be found, however, by considering the more general problems facing schools, the teaching profession and teacher education. The problem has developed over several years and results from apathy and neglect by society. The U.S. has paid the price in a population which is not sufficiently technologically literate.

In this paper Flowers discusses the shortage of science and mathematics teachers by dispelling eight myths often associated with teacher education.

Myth: Schools are Failing

Reality: U.S. schools are not failing. They have accommodated a varied population. With the exception of SAT's, students' performance on other exams has been consistent or risen slightly.

Myth: There are Already Too Many Teachers

Reality: There are not enough qualified teachers in many fields. In the 1970's an overabundance of teachers caused college students to enroll in other areas. From 1970-80 there was a 77 percent decline in secondary mathematics teachers and a 65 percent decline in science teachers. Thirty percent of experienced mathematics and science teachers are taking other jobs.

Myth: Certification Waivers will Bring Good Teachers into the Classroom

Reality: Waivers are bad educational policy and will inhibit attempts to upgrade teacher quality. A survey conducted last year by NSTA indicates that 50 percent of newly employed secondary mathematics and science teachers were considered unqualified by their principals (Walton, 1982). Even intelligent, concerned arts and sciences graduates may not be qualified to teach.

Myth: If We Pay Enough We Will Get the Teachers

Reality: In the near future education cannot match the salaries of business and industry. Thus, to compete, the conditions of teaching must be improved. A partnership of business and industry with schools is essential. For example, businesses could send their employees out to teach in public schools for 3-5 years (with tax credit), and offer summer jobs to teachers. Other suggestions Flowers makes are to reduce teaching loads for beginning teachers, give teachers adequate facilities and supplies and fewer non-instructional duties.

Myth: Teaching is Just a Matter of Common Sense

Reality: Teaching is a highly complex process requiring knowledge of: learners, teaching methods (management), resources, evaluation, educational settings and the teaching profession and ethics that guide it.

Myth: Teacher Education Students Aren't Very Smart

Reality: Studies of students who complete education degrees show that they have GPA's and test scores similar to university-wide averages. SAT's of junior education majors have risen since 1979. Also, junior education majors in a sample of 200 colleges had 2.8 GPA (1981-82), and the average GPA of education graduates was 3.0.

Myth: Teacher Education Students Spend All Their Time in Professional Education Courses

Reality: Candidates for secondary education degrees take "a highly rigorous college program--much of it in science and mathematics." Pedagological coursework is only a minor part of secondary mathematics and science teacher training. In fact, one problem may be that the training mathematics and science secondary education graduates receive may be too technical and advanced. In fact, these graduates may have studied little that is relevant to teaching high school classes. According to Flowers, secondary teachers may need more general science or mathematics courses and more supervised classroom experience.

Myth: A Single Solution is the Answer

Reality: Elementary and secondary solutions are different. The problem of unqualified elementary science teachers has been neglected. Students most need good science teachers in their formative elementary years, where so much can be accomplished (students receptive to new ideas). We need a national policy for dealing with future personnel shortages.

Flowers proposes that if we are to effect lasting improvements in education we must engage in dialogue and research:

- to develop programs and techniques for the early identification of able students to attract them into teaching.
- to re-examine college entrance requirements and the general education components in light of literacy needs in other than the traditional ways.
- to strengthen the support areas for science and mathematics.
- to change attitudes toward the study of science and mathematics.
- to encourage teacher educators to explore deviations from current patterns of teacher education to accommodate new needs and challenges.

Conference Discussion

Three discussants reacted to the paper by Flowers. James Kelly acknowledged that the task Anne Flowers attempted was an enormous one, but expressed his belief that Flowers had not convincingly dispelled the myths she identified. He stated, "...in giving only a one-sentence characterization of each myth, the author fails to explain the content and arguments of the myths she purports to dispel. This makes it difficult to determine exactly what is being refuted...the proposals at the end seem to have no apparent connection with the myths and realities surveyed in the body of the paper, and several of these sound good but seem to be rather shy of meaning."

Kelly further notes that the education of teachers is a complex issue that has no simple answers: "...the author goes on to be prescriptive in areas where flexibility and alternative actions appear to be feasible." Kelly suggests that the paper by Flowers will be well received by some teacher educators but that it will not be received well by researchers or critics of teacher education. He suggests that the paper would be improved by a fuller discussion of history and inclusion of relevant research data. (He also advocates more relevant research in the future.)

Judith Lanier, the second discussant, agreed with much of Kelly's criticism: "Thus, I share a substantial amount of Jim's reaction to Anne's paper in the sense that the myths and the comments on them tend to be so broad and sweeping that it makes it somewhat difficult to tease out the partial aspects of reality or the unexamined questions that might be associated with them." Lanier suggested that problems vary (some schools and teacher education programs are successful but others are not) and that Flowers' refutation of old myths may simply consist of substituting new myths.

Lanier also took issue with Flowers' implicit suggestion that increased knowledge of mathematics and science might have deleterious effects upon teachers' classroom performance (perhaps teachers would be frustrated when they teach mathematics or science in lower tracks), and to Flowers' related suggestion of a possible reduction in the depth of subject matter knowledge required of prospective teachers.

Lanier believes that instruction is improved when teachers have a deep and sound grasp of subject matter (even when they teach lower level courses). However, she acknowledges that this is a personal belief which is not supported by data, and calls for additional research. She stated, "I think it is high time that we increase our research activity and decrease our assertions about the effects of differential subject matter knowledge on the quality of teaching and learning."

Lanier contends that it is safe to assume that teachers cannot teach what they do not know (although Easley takes a somewhat different view), and that it is time to gather more information on the nature of the scientific and mathematical knowledge that teachers have and need. We agree with Porter and Shulman, that it will also be important to identify the beliefs and preferences that lead some talented youth to pursue careers in teaching.

Finally, Lanier contends that there is a paucity of research about teacher education in general, and that additional research will help us to design better programs. She suggests that it is difficult to improve teacher education programs unless we first examine the present curricula and training.

Odus Elliot was the last discussant. Contrary to the remarks of Kelly and Lanier, Elliott "...viewed Flowers' paper not as an attempt to provide a definitive philosophical, polished statement about teacher education, but more as a vehicle for this conference to begin to identify some of the major problems that we see and that we face in teacher education."

In response to Flowers' paper, Elliott stated that in the identification of the problem he would place more emphasis on the economic issues. His rationale is that our industries are raiding schools for mathematics and science teachers because they are "suffering," "scrambling" and "trying to catch up and keep up" with other countries' high technology productivity. Therefore, the private sector has gotten the attention of many political leaders who recognize the importance of having well trained human capital to rebuild the economies of the states and nation.

Elliot suggests that from his perspective at the state governance level, the way to address industry and school problems is to place pressure on our diverse and decentralized education system. He concluded by endorsing Flowers' point that it is very important that teacher training programs in mathematics and science make sure students have adequate exposure to English and the humanities.

CASE STUDIES:

SCHOOL RESPONSES TO THE TEACHER SHORTAGE

Following the general presentation of major papers, three case studies of school districts were presented. These papers present detailed accounts of how certain school districts are dealing with the teacher shortage problem.

THE TEACHER SHORTAGE IN MATHEMATICS AND SCIENCE
THE LOS ANGELES STORY

Rosalyn Heyman

Present shortages were in part brought on by the departure of many Cuban refugees who were hired as teachers in the 60's and the departure of many former engineers (who were laid off when defense contracts moved in early 70's) hired to teach. Both groups discovered that teaching is difficult--they did not know management techniques, learning theory, etc.

Summer Programs

In the late 1970's the district started a six-week summer workshop to retrain teachers in other areas to teach mathematics and science. Teachers were paid a stipend. Also, in the 70's science teachers participated in NDEA workshops in colleges to update knowledge and skills. Funding for these programs is gone now, however.

Internship Programs

Colleges were asked to submit proposals for internships for district employees who wanted to add mathematics or science to their credentials. An advisory board of mathematics and science teachers approved the proposals. Some internships were successful, and others not. Some proved too expensive for teachers.

The same procedure was used to provide programs for teachers holding emergency mathematics/science credentials to get full credentials. This program was very successful.

The latest effort is a joint UCLA/district internship retraining program to train junior high mathematics teachers. Twenty-nine trainees took summer university classes (tuition was paid) and were paid for a three-week workshop (planning, learning theory, management). During the school year trainees take a university course and practicum each semester. The next summer they finish training with a "nine-unit university segment." This district has a full-time resource teacher who visits and supervises the teachers' work in their classes and provides individual and group inservice training. Heyman reports that because 12 of the original 41 trainees dropped out due to difficulty of university mathematics courses, the university "adjusted coursework accordingly."

Investment in People Program

This program is funded by the state.

Program facets:

1. local schools can write proposals for money for staff development in mathematics, science or computer literacy.

2. continued training of 29 teachers in internship program described above.

3. colleges can write proposals to help train emergency credential teachers in mathematics and science.

4. computer-based teacher training program to assist teachers in completing courses for certification to teach secondary mathematics. To implement this facet, five Teacher Education and Computer Centers were established in the state and eight terminals were placed in five district high schools. This Program has failed because colleges are not willing to give credit for Computer Assisted Instruction.

Partnership with Industry, Government and Military

The plan is for industry personnel to donate several hours a week to instruct high school students. This Program has not started yet.

Partnership for Development of National Engineering Resources Project, a group from industry and military, is interested in increased support for college and secondary S&E facilities and incentives to attract secondary science and mathematics teachers. They are exploring 10 possible actions:

1. legislation to allow incentive payment to teachers in fields with shortages.

2. review national legislation to improve science and mathematics instruction--support and lobby.

3. fund science and mathematics chairs at local high schools.

4. provide instruction from industry or military engineers and mathematicians one or two periods a day--

5. use #4 so teachers could be freed to visit industry or observe outstanding teaching.

6. use #4 to provide enrichment instruction.

7. industry provide funds to retrain mathematics teachers.

8. provide money for equipment or equipment to schools.

9. grant sabbaticals to industry or military personnel to teach for a year.

10. sabbatical leaves for teachers to work in industry.

PRIS^{2}M--A PROGRAM FOR STUDENTS BUILT UPON PROFESSIONAL GROWTH EXPERIENCES OF TEACHERS

Douglas Seager

Introduction

This program is used in Rochester, New York (a high technology center) to increase minority student enrollment in mathematics and science courses. A joint venture of business and schools, it has a ten-year funding commitment of $2 million made by 26 local industries in 1978.

There are two full-time staff: one curriculum coordinator works closely with schools to initiate and implement academic programs, curriculum and summer activities and also links schools with industry; and a community relations coordinator links community, schools and industry while promoting program goals to all three. An executive director oversees these links and promotes the program at the highest levels of the three organizations.

Program Components

1. Development of a new junior high science curriculum. The new curriculum provides more direct student experiences, alternative activities which allow some student choice and emphasizes process skills. Students also do long-term projects. Curriculum development also involves many science teachers in a professionally rewarding summer experience as they help develop curriculum.

2. At the high school level the program is designed to promote interest in engineering and in majoring in mathematics and science in college.

To be selected for membership on a PRIS^{2}M team, students must be taking advanced courses in mathematics and science, and make passing grades. Students follow a four-year sequence of coursework. Team activities include a monthly visit to an industrial presentation (based on principles of science) at the site. An additional monthly team meeting after school provides a variety of activities (e.g., science fair project development, career awareness, financial aid programs). Meetings include school faculty and industry experts. Social events for teams are also important and help to develop a sense of belonging which offsets negative peer pressure.

There are three special summer programs: (1) three-week summer science and mathematics workshop (9th grade); (2) one-week biology camp (10th grade); (3) a nine-week "Orientation to Engineering" program includes one week at a university and eight weeks of paid internship at an industry (11th grade).

Teacher Involvement

One problem with mathematics and science teaching is the inadequate intellectual challenge it presents. Teachers are bored, and exciting technological progress is largely passing them by. To develop positive attitudes and enthusiasm, PRIS^{2}M involves teachers in several tasks, most of which they are paid for during outside school hours or summer. For example, each science and mathematics teacher selected to participate authors a new science unit and at least one module for another teacher's unit. This is an inter-disciplinary process and consultants also help (so far 50 teachers have developed units). Pilot testing of the new units is done by science teachers, but not necessarily by authors. This requires inservice conducted by authors/ teachers and feedback sessions.

Unique Features of the Curriculum

Flexibility is a key aspect. There are required units and choice units, and teachers may even include a unit of their own choosing, which is not one of the program units.

In the teacher module, each science teacher serves as a role model by being required to carry out a scientific experiment and share the ongoing process and results with students. Teachers thus incorporate science into their private lives. Seager believes science teachers in particular have not conveyed to students that skills and values learned in the classroom can be utilized outside class in hobbies, visiting museums, gardening, etc.

To help teachers select a problem and study it, PRIS^{2}M has initiated: (1) a series of meetings between industry scientists and school science teachers (personal contacts also enhance pupils' science education); and (2) small grants for equipment/materials teachers need for their research projects. Anticipated long-term outcomes are that scientists will use teachers to carry out supplemental research in science classrooms and summer employment for science teachers.

TEACHER SHORTAGE IN SCIENCE AND MATHEMATICS:
WHAT IS HOUSTON DOING ABOUT IT?
Patricia M. Shell

Introduction

In Fall 1978, Houston had 47 secondary science and mathematics vacancies. However by Fall 1982, there were only two mathematics vacancies and one in science. Shell's paper describes how this change occurred in a district whose student body is 43 percent black, 32 percent Hispanic, 22 percent white.

Houston's Response

First, the scope of the problem was communicated in every possible way to all segments of the community.

Second mile plan. The district developed an incentive pay plan for teachers who teach in curriculum areas or schools with shortages. The plan emphasizes four areas:

1. improving instruction
2. teacher shortage
3. staff stabilization
4. recognition of teaching as a rewarding career

To be eligible for a stipend, a teacher must:

1. hold a valid teacher certificate
2. be assigned to a school
3. be paid on a teacher salary scale
4. have an acceptable performance evaluation
5. have no more than 15 absences in three years
6. be a full-time teacher, nurse or librarian.

Employees may qualify for stipends in each of the following six categories:

1. contributing to outstanding educational progress of students (based on actual/expected school test score averages)--$800

2. teaching in an area of critical staff shortage--$600-1,000

3. teaching in a high priority location (schools with high percentage of educationally disadvantaged students)--$2,000 (Title I)

4. outstanding attendance (absent five or fewer days)

5. professional growth activities--college courses, district inservice

6. unique campus assignment--teachers who teach at a school where no test data are available because of student mobility or because students are not able to be tested with standard tests ($450-750)

The business community has supported the plan and spent several million dollars on it each year. Teacher organizations are opposed; they want across-the-board raises. However, more than one-half of district teachers support the plan.

Among many positive results are the following: vacancies reduced from 195 to 30, turnover reduced 6.8 percent and fewer absences.

Project search. This project is a local district intensive summer staff retraining program which retrains already employed teachers so they can be certified in mathematics and science. The district pays all expenses and gives a $250 stipend per course, contingent upon a grade of A or B in a course. Teachers in the program must agree to remain in the district three years or repay training costs. Applicants are carefully screened. At the end of the first training cycle, 34 teachers were placed in new positions as mathematics or science teachers.

The Houston district is addressing the image of the teaching profession, the number and quality of recruits to teaching and the quality of the teaching-learning process by raising standards for promotion and graduation; using comprehensive staff assessment and assistance; using technology to support instruction and opening two magnet high school programs for the teaching profession.

Conference Discussion

The presentations by Heyman, Seager and Shell were followed by comments by Charles Thomas and E. B. Howerton, Jr. The discussants were generally supportive of the initiatives and directions taken, but added a number of practical concerns that those who implement such plans would need to address (e.g., How do you motivate the average teacher? How do you identify aspects of teacher quality other than the ability to produce student achievement?).

CASE STUDIES:
BUSINESS/COMMUNITY/EDUCATION RELATIONSHIPS

Following the presentation of case study responses to the shortage problem, three papers were given that focused upon how business, community, and political leadership could improve the mathematics and science education of youths.

ARGONNE SUPPORTS PRECOLLEGE EDUCATION IN SCIENCE AND MATHEMATICS

Juanita Bronaugh

Argonne National Laboratory performs nuclear-reactor related research and studies of other technologies. Many of its scientists and engineers have joint appointments with the University of Chicago. The laboratory is currently sponsoring four programs for precollege students in Chicago public schools.

I. High School Summer Research Apprenticeship Program

This program is designed to encourage minority and female sophomores to continue mathematics and science study in their junior and senior years. A six-week summer program offers exposure to many energy-related research programs at Argonne and to the personnel there. Students who participate are talented (upper 20 percent of class; two years of mathematics; one year of biology; one year of chemistry).

The program emphasizes small-group research, computer instruction, nuclear physics, crystallography, environmental chemistry and electron microscopy. Students who complete this program go on to another program conducted by the Illinois Institute of Technology in their junior year. After they graduate, some return to the Argonne Pre-college Program in Science and Engineering (PRE-COOP).

II. Pre-college Program in Science and Engineering

This program gives college-bound high school graduates the opportunity to work with professional scientists and engineers. Competition for admission is high--only 1 in 4 applicants is admitted. Emphasis is on research, and each student becomes part of an established Argonne research team and pursues an aspect of research independently or assists the group. Students write up their projects. (Bronaugh does not say how long this project lasts.)

III. Adopt-A-School

This program was initiated by Ruth Love, General Superintendent of the Chicago Public Schools, in order that schools might utilize outside resources. The Argonne Lab provides scientific support services, tours and educational programs. The program's purpose is to increase the number of minorities in science and engineering careers by having the three groups named above provide technical, financial and administrative assistance to Chicago schools to enrich the curriculum and develop student interest in careers.

Program concepts are to be initiated in three phases:

Phase I. Six elementary schools will participate in a pilot program which includes needs identification, program development, inservice, instructional assistance and curriculum development.

Phase II. Activities will be expanded to include high schools serving the six elementary schools. A sequential program plan will be developed for high schools. Additional elements in this program phase are: peer support system; tutoring; career information and recognition activities.

Phase III. The program will be expanded to include all other elementary and high schools in the Chicago area.

Most program activities occur during school hours.

Two other programs are in the planning stages:

IV. Tomorrow's Scientists, Technicians and Managers Program

This program will be held in cooperation with the Aurora, Illinois schools. Its purpose is to increase the number of minorities entering science, technical and business jobs. It will focus on selected pupils in grades 9-12 and activities will occur outside schools.

V. Saturday Science Academy

This program is for highly talented fourth graders, and will begin with a pilot program in May for 15 pupils for six weeks. Students will develop skills in creative expression of scientific ideas and use of computers in science. Argonne S&E's have prepared the program content and will lecture and give demonstrations. The program will be evaluated before it is expanded.

SCIENCE MUSEUMS AND SCIENCE EDUCATION

Bonnie VanDorn

Many pupils who are interested in mathematics, science, etc. are not being reached through the usual instructional approaches in classrooms. Many schools are therefore extending science education by working with museums. The Association of Science-Technology Centers is an organization which provides information and services to help museums improve public understanding of science and technology. A 1976 survey showed that 93 percent of science centers (museums) work directly with local schools.

The following are examples of educational programs that science centers provide:

1. Computer--classes, rent time, camps, travelling vans

2. Teacher services--help colleges with inservice education, allow teachers sabbatical leave to work at museum, offer incentives for teachers to learn about the museum, hints teachers can use when teaching, curricula

3. Science accessibility for special groups--minority students, women, disabled students and their parents and teachers

4. Gifted students

5. Outreach--most museums are located in urban areas, so many programs emphasize sending vans, etc. to schools in smaller towns

6. Special programs and events--contests, camps, having scientists in community visit schools, TV programs

Such programs can help current science and mathematics education problems in several ways:

1. Museums' unique facilities, technology, and personnel are not available in schools.

2. Informal nature of learning setting compliments classroom.

3. Museums' focus tries to create science enthusiasm in community--promotes school programs.

4. Collaborative history of museums.

5. Museum programs are cost effective.

Current and developing science centers will have a much greater effect on improving science education if the following challenges are addressed:

1. Partnerships--with schools

2. Funding--more needed

3. Research--more needed specifically about museumm education, effects on various types of learners, etc.

POLICY ALTERNATIVES: EDUCATION FOR ECONOMIC GROWTH

Roy Forbes

The last formal speaker at the conference, Roy Forbes, described present work by the Education Commission of the States concerning the shortage of mathematics and science teachers. He stated that when Governor Hunt of North

Carolina became chairman of the commission he saw a need to create a task force to involve political leaders, business leaders, educators and scientists in addressing the relationship between education and economic growth. A group composed of representatives from these three areas suggested three general purposes for the task force as it attempted to improve the educational system. The first was to develop general awareness of the need to take vigorous action to improve education and to help people understand relationships between education and various economic groups. A second purpose was to develop recommendations which could be used at every level (business, education, government) to improve education. The third purpose of the task force was to promote partnerships between business and education. Forbes summarized a number of steps and policy recommendations that will soon be available.

Conference Discussion

Following Forbes' presentation, Shulman cautioned that although business involvement was welcome and needed, the quality and appropriateness of plans should be emphasized rather than how quickly plans are implemented.

Lynn Gray reacted to the papers presented by Bronaugh, VanDorn, and Forbes. He was enthusiastic about the prospects of business/education cooperation, but provided two important caveats. First, he argued that the shortage problem is severe and that most proposals, exciting as they may be, involve few teachers and students. He suggested that we need ways to help the vast numbers of teachers and students who currently populate schools. He noted that there are no immediate short-term solutions. For example, although New York City is in its 15th year of educational innovation, progress is evident now in only 30 or 40 percent of its schools. Gray argues that if progress is to occur, plans must be laid out thoughtfully and carefully, and he notes that it takes time to prepare adequate plans.

His second qualification on the business/education partnership concerns how resources would be utilized. He stated, "My last comment is a bottom-line comment. One of the things that I think happens in these partnership linkages is that we spend a lot of time thinking of the roles and relationships of the various players but we have not learned how to focus on the children and what they really need." Quick action and more resources will not produce good solutions unless a sense of purpose and direction is articulated." This position was stated earlier by Robert Yager.

THREE VIEWS OF THE CONFERENCE

In the final segment of the program three individuals were invited to respond as they wished to the conference proceedings. That is, they were encouraged to discuss new data or problems as well as to react to previous presentations and discussions. We can only briefly and selectively summarize their viewpoints here.

Steven Davis argued that one source of confusion for him as a new teacher was the belief about mathematics that, "you were supposed to teach it to make everyone a mathematician" and he feels that this is a common mistake. He agreed with Roy and other presentors that a major task is to make the curriculum more immediate and applicable to the average student. He noted that microcomputers are being placed in more and more classrooms, even though we have no research evidence about how they can best be utilized. He notes that it is ironic that some teachers use the pocket calculator to balance their checkbooks or to compute grades, yet refuse to allow students to use pocket calculators. He suggests that there is a vital need for leadership from teacher educators if classroom teachers are to use microcomputers and other forms of technology well in the classroom. He further suggests the need for teachers to become quite knowledgeable about technology if they are to help students become literate users of technology.

Robert Stake argued that the modern teacher needs "to be more reactor, commentator and director of continuing learning." He contends that standard assessments of learning are too narrow and are counterproductive. He stated, "we don't know what youngsters will need in their lives. We don't know what the demands of the future will be. We have to rely on our best guesses, of course, but we should also rely on the intentions of teachers and the intuitions of youngsters." He insists that one way to increase student interest in classroom learning is to give students more choice and to increase teacher commitment. We need to give the teacher more responsibility in selecting options for students. (Earlier, Porter reported that teachers did not assume these responsibilities and Kilpatrick and Wilson argued that teachers were not well trained for such decision making.) In essence, Stake argues that the curriculum should be more responsive to individual students as well as teachers. Furthermore, he suggests that common goals and standards prevent rather than promote educational excellence.

The final discussant, Naama Sabar, raised an interesting and compelling question from her international perspective: "How come a country that in most fields of science and technology competes so successfully with all countries in the free world, due to your wealth of ideas, quality of manpower, natural resources and facilities, has reached this present crisis in the area of teaching, exemplified here in science and mathematics education?"

Sabar believes that the crisis is in part due to an unwillingness to invest resources in teachers or to devise ways to lend status to the role of classroom teachers. In response to the need for teachers to be technologically literate, she raised the question of how many teachers could afford to purchase a microcomputer. She noted that an automobile repairman makes good money, that competent scientists have status, and that even a stage director can earn a good salary and have status (e.g., be nominated for a Tony Award). However, teachers receive little money or status. She stated, "yet, an exceptional teacher, if at all, will get recognition from his own association, and the local Rotary Club may acknowledge him as well." She suggested that, "The United States government should view education as part of its defense and security (and spend funds accordingly) if it is to maintain its position as international leader."

DIRECTIONS FOR ACTION

The summary of conference papers and discussion does not provide a clear mandate for action to resolve the teacher shortage and general literacy problem (teachers, citizens, students) in mathematics and science. Certainly there were important and healthy differences among participants in how they define the problems and in the steps they believe are most likely to solve the difficulties. The conference provided a broader understanding of the problems, identified several points which need resolution (and which call for basic research and development activities), and produced examples of what some agencies, school districts and universities are doing in response to the teacher shortage and the literacy problems. The information, ideas and problems identified at the conference will be of value to school systems as they deal with these issues and to decision makers who face difficult but important policy challenges.

As we write this document in early March, several states are passing legislation that addresses certain aspects of the problem (e.g., higher curriculum standards). The Congress of the United States is now deliberating legislation that will provide badly needed funds that can be used to help correct deficiencies in these areas.

Considering the rapidly growing public concern over these issues and the money that Congress will soon make available, we believe it is likely that the money appropriated will be poorly spent in most instances. Although the funding will probably be inadequate, careful thought before these funds are spent will (or would) have more significant, long-term effects than quick spending will achieve. We acknowledge that there is an acute shortage of mathematics and science teachers, and particularly of well-qualified teachers. The problem is enormous and important and the continued economic productivity of the United States depends upon a successful, long-term response to the shortage and the related problem of scientific and mathematical literacy. Clearly, some action must be taken immediately; however, we believe that certain aspects of the shortage can best be solved by discussion and basic research rather than by quick spending and radical changes in the curriculum that are based primarily on short-term reaction or impulse.

What, then, are the issues that the participants at this conference believe should be studied? In response to this question, we will discuss topics upon which there was reasonable consensus among participants and general problems which cannot be adequately solved by individual states or school districts. <u>We view three broad areas as meriting attention: curriculum reform, process research on classroom learning and instruction and increasing public support (which involves altering salaries, the status and duties of the profession) of classroom teachers.</u>

Curriculum Reform

The most prevalent view expressed at the conference about the current status of mathematics and science education was that 95 percent of our students (and citizens) need better mathematics and science training, not the top 5 percent. Participants generally agreed that the present curriculum was producing an adequate number of advanced scientists and that our supply of exceptionally talented students is not in jeopardy. Still, most of the programs described at the conference were designed to identify and to educate gifted and/or minority youth. This is of course understandable (and we need such programs), but it is regrettable that more attention has not been placed upon improving the mathematics/science curriculum for the average student. The most important issue concerns what can be done to prepare citizens who understand and are therefore capable of using technology in intelligent and appropriate ways and thus of making informed decisions about technologically-related issues. The answers to this question were varied and complex, but the most frequent response was the call for a more appropriate, relevant curriculum and for qualified teachers to implement and expand it (we will return to the teacher issue later).

Beyond the frequently stated opinion that curriculum reform was needed, there was little agreement as to what direction this reform should take (readers who wish to scientifically conduct their own content analyses of conference proceedings should review this massive report...we encourage replication efforts). In part, this is because the conference was organized primarily as a problem stating group and hence, little time was spent discussing the new curriculum. Because of declining test scores and student interest, dissatisfaction with many science and mathematics textbooks, etc., there is societal consensus that curriculum reform is needed. But poor performances on assessment instruments do not tell us what abilities should be measured or how to correct identified problems.

To many citizens and educators, curriculum reform means more courses and indeed many states have passed legislation which requires that students take more courses in mathematics and science. However, considering that many students develop a distaste for science in elementary school, mandating more course work without seriously studying the quality of science and mathematics curricula, particularly in the early grades, may exacerbate the problem.

Although most papers at the conference addressed the problems of mathematics and science education in secondary schools, we believe that if secondary science education is to be improved, it will be necessary to simultaneously increase both the quantity and quality of science education at the elementary level. Studies by Ebmeier and Ziomek (1983) and Stake and Easley (1978) indicate that most elementary pupils receive little or no instruction in science. In a study of 75 teachers in Grades 2-6, Ebmeier and Ziomek found that an average of only 15 minutes per week was spent on science in second grade classes. By fifth grade, this time had only increased to 43 minutes. Furthermore, the time spent on science in most classes was considerably lower than what the district recommended.

Still, we need further descriptive data on which to base curriculum reform efforts. Until we have such information, it is hard to know how much time should be taken from other curricula areas and devoted to science. Schools have many subjects of limited value (especially secondary schools), and curriculum reform in mathematics and science must involve an examination of the total curriculum by mathematicians and scientists, teacher educators and classroom teachers to determine how the curriculum should be altered.

Scientific knowledge is presently growing at a rapid pace and it appears that many technological advances will be made in the next few years. If the U.S. hopes to prepare its citizens to live in a world heavily influenced by technology, educators must determine what scientific information and processes students should know. What do we mean by a "technologically literate" citizen? Although there is no simple answer to such a question, we believe that it is imperative that the current curriculum be described and serious scholarship conducted to determine how it should be modified.

Although we acknowledge that the curriculum needs reform, we are not certain what the nature of that reform should be. In fact, it will be impossible to make useful changes unless there is a clear understanding of what the curriculum is and should be. We therefore urge that at least some appropriated funds be spent in 1983-84 for commissioned work designed to identify possible areas of reform and ways to achieve improvements. What do we want students to be doing in classrooms in 1993? What are the criteria that we will use in 1993 to determine whether or not the money and time expended in the past ten years have substantially improved technological literacy? Serious study of these goals in advance might make it more likely that curriculum reform efforts will be at least moderately successful.

Some excellent study of curriculum reform has been made. For example, the National Council of Teachers of Mathematics has produced a useful, comprehensive statement outlining the mathematics curriculum needed in the 1980's. This report strongly advocates more attention to problem solving but does not define problem solving at a functional level. Funds invested in carefully designed conferences, research studies and development activities might yield criteria that could be used to construct and to evaluate curricula. With criteria and a broader understanding of what is meant by problem solving (and other terms such as "scientific literacy") we could begin to answer a variety of practical and important questions such as the following: How do we operationally define problem solving? How do we differentiate appropriate problem-solving teaching from inappropriate or poor instruction? What percent of our teachers attempt to teach problem solving? How do teachers' definitions of problem solving compare to those called for in curriculum reform efforts? How do teachers whose definitions of problem solving correspond with those advocated in the curriculum reform teach (or structure their classes) problem solving? What is appropriate and inappropriate about present curriculum experiences for students?

Funds invested in development designed to clarify intended curriculum reform could use new technology (as well as describe it). For example, competent teachers who include problem-solving instruction in their curricula could be identified and videotaped and these tapes could be shown to other teachers to demonstrate techniques and activities which characterize effective problem-solving instruction. We therefore believe that if classroom teachers, educators and scientists are given sufficient funds it would be possible to identify and develop more appropriate curricula and to demonstrate them more effectively than the rapid innovation that has characterized past change in American curricula allows. As any student of educational history realizes, attempts to clarify terms involved in curriculum reform efforts (discovery learning, open education, process science, new mathematics) have traditionally come only after a reform has been tried and subsequent evaluative data are negative or uninterpretable. If conceptual clarity were achieved and implementation measures constructed, it would be possible for empirical research conducted in 1984 and 1985 to determine whether new curricula had positively affected students' skills and interest in science and mathematics.

Although we do not advocate a national curriculum, we do believe that the delineation of key curriculum and instructional terms is important. For example, there are many questions concerning instruction about an important mathematics concept like "variable:" When should it be introduced in the curriculum? What should follow? These are issues that individual school districts cannot adequately resolve with existing budgets and personnel.

In essence, each day in American classrooms, thousands of informal "field experiments" occur when teachers use their own approaches to present various concepts or principles contained in school curricula. There is growing evidence some teachers cannot improve upon the poor quality of text materials (because of inadequate backgrounds in science and mathematics) and thus distort the concepts they intend to teach, so that many students' misunderstandings of some concepts are not corrected, despite instruction. Furthermore, research on instruction in specific scientific concepts in 14 fifth-grade classes (Eaton, Anderson, & Smith, in press) demonstrates that many students bring to the classroom misconceptions about scientific concepts such as light and vision. In this study, some misconceptions were reinforced by the textbook and the accompanying teacher's guide. It is therefore not surprising that even after 6 weeks of instruction, three-fourths of the students studied still held basic misconceptions about these concepts (see Brophy, 1982 for a detailed discussion of teacher distortion of intended instruction and dependence on textbook materials).

<u>Because many teachers do rely heavily on textbooks and teachers' guides for instruction, any attempt at reform of curriculum and instruction must necessarily include a careful examination of textbooks</u>. Freeman, Kuhs, Porter, Floden, Schmidt, and Schwille (in press) suggest that the textbook a teacher uses largely determines the curriculum students receive. However, these investigators found that the mathematics curricula presented in four textbook series which dominate the market vary considerably. They also found considerable differences between the content of various textbook series and that measured by some standardized mathematics achievement tests.

One recent criticism of the science curriculum is that it is passive, that students learn the knowledge of science (facts, concepts, findings...generated by others) but have little opportunity to engage in the process of science. Telling such teachers to include more science process and less content in their curricula is as likely to add to the problem as to correct it. Such a recommendation would be variously interpreted and implemented. In addition to study to provide a purpose and direction to general curriculum reform, we need research and development that will help teachers understand major scientific concepts and learn alternative ways in which such concepts can be taught (to determine how the general goals of curriculum reform could be implemented in specific instances).

Although there is evidence that effective instruction can make important differences in how much students learn and retain, most of this research has not examined the learning of specific and subject matter concepts in particular contexts. Some funds should be designated for identifying important curriculum concepts, devising interesting ways to present those concepts and/or to allow students to discover them. Such work could be completed at a national level by teams composed of teachers, educators and scientists. Ultimately, the value of such work should be tested by empirical research.

We suggest that teachers would benefit from viewing videotapes of competent, talented teachers conducting classroom activities related to key concepts or issues (variable, quantam theory, place value, equivalent fractions). Although it would be impossible to film instruction in many concepts (at least initially), it seems important to assemble video libraries that illustrate the process or problem-solving skills called for in relation to particular concepts as well as to the areas of science and mathematics generally. Carefully selected video lessons would be an improvement over most classroom observation, and videotapes could be supplemented by discussion of salient aspects of teaching situations. The potential is especially great in science, where time lapse photography and other techniques can allow students to observe the efforts of an intervention or to see change occurring over time periods, and thus to get the benefits of an experiment, when actually doing one experiment in the class might be too expensive or time consuming, or otherwise unfeasible. A variety of technological advances have occurred in the past decade, but teaching has been largely unaffected by them. Such development work is cheap and relatively straightforward, and it is therefore surprising that so little has taken place.

Ultimately, such work might lead to a better understanding of issues such as <u>productive strategies teachers can use, problems or misunderstandings students are likely to develop when attempting to learn concepts, how these misconceptions can be detected and what specific strategies teachers can use to help students with particular misunderstandings</u>. Such basic information could improve vastly elementary and secondary education in this country. Some research in this area has been completed (see Brophy, 1982), but it has not been organized around important subject matter concepts.

<u>Simulation/Curriculum Development</u>

Considering that technology can also make complex phenomena concrete and accessible to students, one wonders why more first-rate simulations and videos illustrating scientific processes are not available. For example, some of the complex time/motion concepts in physics are easy to depict on video. Videotapes of important experiments in science would do much to allow students to see scientific data being collected and to witness the process of knowledge being accumulated over time until it has practical consequences. Appropriate, selective use of a few demonstrations of the scientific process could help students to develop a respect for the need to measure carefully, to change perceptions as data accumulate, etc. Naturally, videotapes would not be a substitute for students' actual conduction of, or involvement with, science experiments.

Although curriculum goals are affected by local needs and preferences, the cost of producing exemplary scientific videos and simulation activities is so high that few school districts could afford to develop them. However, once produced at the national level, they would be valuable resources for many school districts.

Several participants at the conference suggested that few students actually apply the principles of science before they pursue advanced degrees. Legislation presently being acted upon in Congress involves expenditures for the purchase of new scientific equipment as well as the repair of existing laboratories. Students undoubtedly need laboratories if they are to practice science; however, many teachers will need training in order to use new equipment.

Improving curricula and bringing technology into schools where teachers are not prepared to use them will create massive training needs which will require attention and funds. For example, local districts will need help in acquiring, maintaining, and using new equipment appropriately. National research and development activities should be conducted to help local school districts evaluate their success in training inservice teachers to use new curricula and equipment.

Teacher Education

If the public school curriculum is to be improved, then careful attention must be paid to the teacher education curriculum and funds need to be invested (as Lanier and Porter suggested) to study the relationship between knowledge of mathematics and science and classroom teaching. We need to know the content of teacher education programs if such programs are to be evaluated and improved. Unfortunately, we have a paucity of reliable information about how teacher education programs affect teachers' beliefs, knowledge and skills and how short-term training influences long-term teaching performance.

Although some teacher education programs are helping teachers learn about and utilize technology (computers, video simulation, etc.), we suspect that many are not. Teacher education institutions face complex decisons as they attempt to allocate scarce resources. For example, they must decide whether teachers should be familiar with computer simulations or be able to design simulations. That is, should teachers merely know where to obtain computer software or should they know how to improve inadequate software themselves?

Another important issue which teacher education institutions must address concerns whether elementary teachers should be trained as generalists (as most currently are) or as specialists. In order to possess a thorough knowledge of subject matter in any area, multiple, diverse curriculum materials and relevant instructional techniques, elementary teachers may need to be trained as specialists. Such training may be especially necessary for effectively teaching a subject such as science, where new information and developments occur rapidly.

It seems to us that some federal support and subsequent research (guided by agencies like the National Institute of Education and the National Science Foundation) could help to indicate in more detail how scarce resources can be used advantageously in teacher education programs. It would be pointless and wasteful for each school district to develop its own curricula and programs for improving the technologically-related skills of teachers and students.

Classroom Research

Clarification of curriculum goals in mathematics and science should make possible focused but comprehensive research on instruction in important topics in mathematics and science. To obtain curriculum goals, however, it will be necessary to conduct basic research on classroom processes related to these goals. In this section we will describe an important but neglected curriculum area in mathematics, problem solving. This discussion illustrates why research is desirable if improvements are to be made in classroom instruction and in learning.

In a recent examination of much of the mathematics education literature, we found many statements concerning how problem solving should be taught; however, we found no careful analyses of classroom instruction in problem solving. There are critiques of textbooks and critical and insightful examinations of student performance. Indeed, some of the research illustrating that students can answer mathematical problems correctly without understanding them is quite important and intriguing. Still, it is curious that nowhere in the literature can we find statements describing what takes place when teachers teach problem solving. How do classroom teachers define problem solving and how do they attempt to teach it? How much time is spent on problem solving? At present, there are no dependable data with which to answer such questions. It seems to us that if one wants to improve the mathematical problem-solving ability of students in American classrooms, these questions must be answered.

Thus, mathematics educators should conduct observational studies of classrooms during instruction in problem solving, particularly in classrooms of teachers who are especially adept at teaching problem solving. There are both theoretical, conceptual and empirical reasons for conducting such studies. Polya (1966) notes that solving problems is very much a practical art and, like swimming or playing the piano, it can be learned only by imitation and practice. He suggests that in order to become a problem solver, one has to solve problems. He points out that one of the ways students can become more skilled at problem solving is by having active teachers who can demonstrate the process by formulating choices carefully and can illustrate ways in which to deal with proposed problems. We realize that there are many alternative ways to characterize problem solving; however, Polya's emphasis is plausible and provides a rationale for examining ongoing classroom instruction.

Similarly, it appears that students are deficient in other important mathematical areas. Such "problems" can also be remedied through careful observation and experimentation (for some recent work on estimation skills, see Reys and Bestgen, 1981).

There is ample documentation from the mid 1970's and early 1980's that we can gain valuable information by studying competent teachers. Several extensive research programs funded by the National Institute of Education provide observational evidence that teachers vary in how they think, act and use time in the classroom. Furthermore, these variations among teachers have been related to student achievement in several field experiments (see Gage 1983; Brophy 1979, 1983; and Good, Grouws, and Ebmeier 1983).

We know considerably more about classroom teaching than we did a decade ago. In 1973, our information about the effects of classroom conditions on student achievement was weak and contradictory. In the ensuing ten years research (much of it influenced by funds and coordination from the National Institute of Education) on basic skill instruction, especially in reading and mathematics, has moved from a state of confusion to a point where several successful experiments have been conducted. These studies, in contrast to less sophisticated and often methodologically flawed research that took place in the past, illustrate that teacher behavior can significantly affect student achievement.

Furthermore, there is evidence that the skills effective teachers use can be taught to other teachers. In building a program of <u>active mathematics teaching</u>, Good and Grouws (1979) began by <u>observing</u> how more and less effective teachers (using student performance as the operational definition of effectiveness) taught. We combined this information with other research in order to build a teaching program that could be tested in intact classrooms. Findings showed that the program had a positive impact on student learning and that most teachers could implement the program without much difficulty. We felt that too much mathematics work in elementary schools involves a brief teacher presentation and a long period of seatwork. Such brief explanations before seatwork do not allow for meaningful and successful practice of concepts that have been taught; and the conditions necessary for students to discover or use principles on their own are also lacking. The program helped some teachers to overcome these problems.

The argument here is that much can be learned from the serious study of practice. As Flowers, Lanier and Kelly noted, many myths about educational practice exist, in part because we possess few data with which to describe practice. What data we do have indicate that teaching practice is much more varied than most people currently believe and hence, simple, generalized recommendations (e.g., increase time on task) will do more harm than good. Some participants at this conference suggested that teachers need to talk less and let students do more science. However, in many classrooms, teachers hardly talk at all and students are left to complete dismal "science" worksheets. In such classrooms, teachers should talk more (about the meaning of science; the concepts being studied) and students do not need to do more science, but a different science. Curriculum reform without descriptive research is, in our opinion, self-defeating.

Although much recent research examines basic-skill instruction, there is reason to believe that other processes could be effectively studied by the observation-development-field experiment research approach described above. If goals of curriculum reform and key concepts are identified, research could be directed at these areas.

The focus of such future work should not be limited to teachers. A similar observational model for understanding mathematics learning has been used by Krutetskii (1976) to study how excellent students attempt to learn mathematics. Also, as noted earlier, a growing number of researchers are interested in student behavior (e.g., time on task) and perceptions (Do they view problem-solving assignments as a challenge?), and such work can help to make instruction more effective (see for example, Peterson & Swing, 1982; Weinstein, 1983).

Many strategies for promoting effective learning are not common aspects of classroom practice and thus the study of practice is not the only way to bring about desirable change. For example, Rosenshine (1983) demonstrates that successful school programs can be achieved through systematic thinking and development independent of sustained observation of teachers.

Our purpose here is not to identify research areas, questions or paradigms that merit support. We do wish to suggest a general direction which we believe some future research should take.

Past research has been aimed at the curriculum, <u>or</u> teachers, <u>or</u> students. As we stated earlier, if research is to be effective, its context must be focused. However, within the particulars of a given research study (e.g., middle school science classes), research needs to become more comprehensive. We need to know the concepts and <u>subject matter</u> issues that are being studied as well as how <u>teachers</u> and <u>students</u> think and behave when they study particular concepts. Furthermore, curriculum research tends to examine content, sequence, and pace issues and to ignore what teachers and students do when they actually <u>study</u> curriculum.

We also believe that teachers and students need better science textbooks and teachers need manuals to help them understand the concepts and processes they teach. Without better materials and better illustrations of effective teaching/learning environments, students' scientific literacy will not improve.

More complete theories of instruction in mathematics and science (and of instruction generally) must also be developed. Lee Shulman suggested at this conference that there should be more structure to classroom instruction, and that students' understanding and knowledge of a subject should accumulate and develop over time. According to Shulman, the last short story taught in an English class or the last unit in an algebra course should be taught/learned somewhat differently than the first material, because students hopefully have learned concepts, principles and procedures for analyzing stories and problems. However, we have no instructional theories which enable us to examine these issues and little extant empirical data upon which to build such theories. As Bruner (1966) noted, a theory of instruction needs to describe the ways in which knowledge and concepts can be effectively sequenced so that students' understanding of instruction is enhanced.

Recognition of Teachers

In a variety of ways conference participants expressed their belief that teachers need more pay, recognition, public support and better working conditions. We agree. Many teachers have difficult jobs, are poorly paid and are frequently the targets of societal criticism. However, we must recognize that there is variation among teachers. Unfortunately, educators, researchers, the public and even teachers suggest that most teachers behave alike and have similar effects (whether positive or negative) on students. For example, some conference participants suggested that teachers are not capable of modeling problem-solving strategies, and other researchers indicated that most teachers teach mathematics in the same unproductive fashion. Others suggested that the study of teacher behavior has been unproductive and recommend that research address other areas. We submit that these generalizations about teachers and teaching often result from the failure to recognize variations in teaching performance. In reality, some teachers are worthy of emulation and others are not; some offer exciting, productive classrooms and others' classrooms are poorly organized and taught, and little productive learning occurs.

Because of society's failure to recognize and to reward satisfactorily competent teachers, many teachers (particularly the best ones) have left teaching. They do not want to work at an occupation that has low pay, little intellectual stimulation and little opportunity for advancement. As Wimpelberg and King (1983) state, "To endure the conditions accompanying life as a teacher, the person must have elaborate support systems, unusually high commitment to the roles and tasks of the job, or--on the negative side--no real occupational alternatives." Many conference participants pointed out that teacher salaries (especially those of experienced teachers) are too low and that teachers continue to obtain salary increments that are considerably less than those of other white-collar workers. There appears to be widespread and growing dissatisfaction among teachers with their pay and professional status.

Schlechty and Vance (1983) present data which indicate that too many of the most effective teachers are leaving the profession and that many students with higher aptitudes no longer enter teacher education programs. Despite evidence that the pool of bright students seeking enrollment in teacher education programs is declining, some teacher education programs still attract qualified candidates. For example, at the University of Missouri, students who enter the teacher education program rank at the 70th percentile of their high school classes (this figure has remained stable for 10 years).

Though we face a serious problem at present, it is still a solvable one. However, after another two to five years of neglect (particularly of the salary issue) and the loss of a higher percentage of capable teachers, the situation may become unmanageable. Because of a decline in the overall quality of teachers, it is more difficult for an individual teacher to be effective. Furthermore, because of increased public concern over the performance of public schools, there is a growing unwillingness to fund public education.

There is much that can and should be corrected in many teacher education programs and in public schools. Besides increased pay, there are other ways in which teachers can be compensated. For example, more documentation of teachers' preferences concerning the conditions and professional duties associated with teaching would be useful. Among the many options that could be used to improve teaching conditions: summer employment opportunities in business or industry; reducing record keeping and other clerical duties; three to four hours a week during the school day for planning; release time to observe other teachers, discuss instructional strategies and view classroom films with other teachers; the chance to specialize (Why should elementary school teachers be asked to be knowledgeable in several subjects?); helping educators and researchers to develop curricula; free college tuition for computer and science classes; more involvement by college and business personnel in actual classroom instruction and preparation of learning aids. Although most current legislation is intended to encourage persons to become mathematics and science teachers, the conditions of teaching must be altered so it becomes a more challenging, interesting occupation. We are especially encouraged by proposals that advocate bringing non-teachers to the classroom to share knowledge and expertise.

In the final section of the paper, we would like to discuss a salary plan that has received considerable attention, and the possibility of national study and development to help guide local school districts in devising salary plans and allocating resources.

Master Teacher

We have suggested many ways in which teaching can be made more attractive and prestigious: serious study of teachers; the sharing of teachers' successes with the public; raising salaries; improving working conditions; and altering teachers' duties (role). Yet another way to improve teachers' morale and classroom performance and thus to attract more talented persons to teaching is to identify and reward exceptional teachers.

Teachers who achieve excellence in classroom instruction, curriculum development, and supervision and training of other teachers should be identified and rewarded. Unfortunately, teachers who have taught for seven to ten years and who have similar training receive similar compensation, irrespective of whether they work 35 hours a week and perform dismally in the classroom or work 75 hours a week and perform superbly. The reward structure of teaching is flat (unstaged) and salaries are usually based on years of classroom teaching and the number of post-graduate courses completed. There is little opportunity for advancement, and most teachers reach the apex of the salary schedule in about 15 years. At the conference, Terrel Bell, Secretary of the Department of Education, also advocated increased pay for master teachers.

However, the potential advantages of a Master Teacher plan are not assured, and all incentive plans have problems. Participants at this conference argued that the problem facing American Schools was a decline in general teacher morale and that this problem needs attention if the teacher shortage in mathematics and science is to be remedied. The present pay of average teachers is much too low, and if funds for master teachers' salary increases come at the expense of upgrading teachers' salaries generally (a common teacher objection to this plan), general teacher morale is likely to be negatively affected. However, most differential pay plans proposed to date require that funds be added to educational budgets; money is not being taken from some teachers to pay others. To the extent that funds for master teachers are part of a plan to increase the salaries of all teachers (at least to some degree), this is an encouraging strategy to explore.

Others argue that decisions about who should be designated master teachers will cause dissension among teachers. First, many teachers believe they are outstanding teachers and will be disappointed when not selected as master teachers. Furthermore, some fear that the criteria for selection will relate more to political savvy than to teaching skill or subject matter knowledge. However, the obvious fact that reliable criteria will be difficult to establish does not mean that we should not try to define levels or stages of professional advancement in teaching. We must be certain, though, to define the criteria carefully, revise and review such criteria periodically and seriously study related issues (who sets the criteria, how judgments are actually made) if such plans are to work.

While rewards for teachers are important, a large measure of the value of such a plan lies in the discussion it encourages about what constitutes excellence in teaching as citizens, public officials, teachers and teacher educators debate this issue. A focus on excellence in teaching would help to identify positive aspects of schooling and enable the public to become more aware of the complexities of teaching. An increased public awareness might lead to greater gains for all teachers (i.e., an increased public willingness to fund higher salaries). Further, master teacher plans could add to our knowledge of classroom practice and increase our capacity to illustrate to other teachers strategies that are particularly interesting or effective. For example, master teachers could use videotapes of their classroom performance, curriculum units they have developed or students' products in order to assist in the training of other teachers.

We suspect that master teacher plans will have more effects in some school districts than in others and that in too many cases funds will be spent in ways that will not encourage or reward competent teachers. Many plans address the improvement of teaching generally and the need for master teachers (see for example, Schlechty and Vance, 1983). However, an immediate attempt to identify and examine issues and problems associated with the implementation of master teacher plans and alternative ways of responding to these problems would involve money well spent to provide important technical and conceptual support to local school districts. Although local districts need to identify and to reward those school processes and products that they value, it seems a waste to require every school district to address a number of sophisticated technical questions that require the attention of economists, psychologists (How much money is necessary for real incentive?), sociologists (How can the potentially divisive effects of competition be minimized? How should career ladders be structured?), as well as classroom researchers, subject matter specialists and measurement specialists. If the plan is to work, serious conceptual study must occur. It will probably be necessary to define several stages in the teaching career ladder (each involving extra compensation) toward the final status of a master teacher. At each stage teachers' professional duties could expand to include curriculum development, assisting with research and supervision and training of other teachers.

Conclusion

The shortage of qualified mathematics and science teachers is an important problem that merits immediate expenditures and action. There is considerable evidence that science is infrequently taught in elementary schools (e.g., Ebmeier and Ziomek, 1983). Furthermore, participants at this conference generally agreed that instruction in mathematics and science is often inadequate, however, because of a lack of research in this area, few participants described specific changes which are needed. Not only do we need more and better qualified teachers, we must also have improved curricula, textbooks, instructional theories and procedures for making mathematics and science more meaningful. Although it may be appropriate that some additional time should be spent on mathematics and science instruction, the quality of the curriculum and the quality of teaching should be our most important concern.

Before science and mathematics curricula and instruction are altered effectively, however, educators, researchers, mathematicians, citizens and teachers must comprehensively assess the curriculum and instruction currently offered in American schools in order to make intelligent decisions about changes which are necessary. This is because we not only need citizens who are scientifically literate, but citizens must also have a sense of history, the ability to express themselves and an appreciation of and skills necessary for participating in the democratic process, etc.

It is clear that the entire American public school curriculum needs serious study. We believe that many courses in the present curriculum are unneeded and that evaluation and reform of general curricula are necessary steps if we are to take appropriate actions in reforming mathematics and science curricula.

Long-term solutions are possible and funds should be invested in national research and development. The problems related to curricula, teacher shortages, technology and instruction are general ones. Local school districts currently have limited options for addressing such issues (e.g., they can choose among poor curriculum series). However, state and local districts can utilize the results of national research and development to examine more alternatives and criteria for making decisions about improving curriculum and instruction.

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